Near Field Ground Motion in Earthquake Disaster Mitigation Plan by Local Governments. Kenzo Toki. Graduate School of Civil Engineering. Kyoto University

ACTIVE FAULTS IN EARTHQUAKE DISASTER MITIGATION PLANNING

by
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Abstract

The 1995 Kobe earthquake gave impact not only to the inhabitants of the area but also to those people concerned with local earthquake disaster mitigation issues. Most of local seismic disaster mitigation planning have considered both of interplate earthquake that occurs along off coast of Japan archipelago and intraplate earthquake which has epicenter within inland area. The latter, however, had relatively less effects on earthquake disaster issues. This has been caused by the fact that the expected intensity of ground shaking due to intraplate earthquake is less than that of interplate earthquakes because of long return period.

Knowing the occurrence of Kobe earthquake that is a typical intraplate earthquake from the seismological point of view, the basic concept of scenario earthquake is completely changed, particularly in Kansai area that includes such cities of the western Japan as Kobe, Osaka and Kyoto in such way that the earthquake disaster mitigation plannings of local governments are established under the assumption of rupture of anticipated active faults regardless to the recurrence period of each fault. However, this kind of approach is adopted only in Kansai area that felt the Kobe earthquake.

Ground motion is numerically calculated by making use of recent scientific achievements. For longer period range than 1.0 sec., the ground motion is determined from numerical analysis of response of three dimensional near surface ground model subjected to disturbance generated from point source on the fault plane under consideration. Short period component of ground motion is determined as an inverse Fourier transform of the spectrum at a site that is calculated by multipying the source spectrum to the amplification property of the site. In these numerical simulation, various combinations of distribution point of rupture on each fault plane are assumed to make a parametric study. Resulting time records are used in determination of spatial distribution of intensity of ground shaking due to each anticipated active fault and in numerical computation of response of structures and facilities subjected to the ground shaking for determination of safety and retrofitting of existing structures against the major earthquake of the future.

Reexamination of earthquake disaster mitigation planning of local government has been undertaken not only for seismic ground motion due to active fault as a hazard but also for design method of structures utilizing the recent development of earthquake engineering. Fundamental research should be urgently promoted to respond to the needs for the development of earthquake disaster mitigation planning and earthquake resistant design standards. For this purpose, the Ministry of Education, Science, Sports and Culture has given the research grant to "Fundamental Research for the Mitigation of Urban Disasters by Near-Field Earthquakes" for four years. This project has 8 research subjects and some of them will be much more successful my promoting joint researches between US and Japan because both countries have similar situation in both hazard and disaster due to active faults in urbanized area.

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Topic Description and Policy Issues

1995 Kobe earthquake (Hyogo-ken Nanbu earthquake) gave an impact not only to inhabitants of the area but also to everyone who are engaged in earthquake disaster mitigation issues all over Japan because no one had anticipated the occurrence of intraplate major earthquake. More than 6,000 people lost their lives by this event and most of them were killed within very short time. Duration of the event was only about 11 seconds and this earthquake was a typical right lateral strike slip fault. This type of earthquake occurred frequently in the history of earthquake in Japan but it goes back to 1948 that an inland earthquake took place in Fukui and 3,800 people were killed by this earthquake. After this earthquake, we had many major earthquakes but most of them were interplate earthquakes of which magnitude reaches sometimes to 8.0. For instance, we had 4 major earthquakes along Japanese archipelago in last 4 years but only a few people were killed by each earthquake.

Then Japanese people misunderstood that even a major interplate earthquake seldom kills people and the inland intraplate earthquake rarely takes place. However, last 50 years is very calm period from seismological point of view and such calm period is rare in the history of earthquake in Japan. Thus, we had not been well prepared to inland earthquake that occurs near urbanized areas and most of earthquake disaster mitigation issues have assumed the occurrence of interplate earthquake.

Recurrence time of intraplate inland earthquake is much longer than that of interplate earthquake. We, however, learnt a lesson that many people will be killed by intraplate earthquake once it occurs even though the recurrence time is order of 1,000 years. Thus, the basic concept of earthquake in seismic disaster mitigation plan of local government in Kansai area such as Osaka, Kobe and Kyoto has been changed after the Kobe event. However this change of concept has not been accepted in other area including Tokyo and therefore this is not covering entire Japan.

The Japan Society of Civil Engineers also has supported this concept and issued an recommendation of similar concept, namely consideration of inland earthquake with equal weight with interplate earthquake in seismic design of structures.

Background

Most of local earthquake disaster mitigation plan in Japan consider both the interplate and intraplate earthquakes. The epicenter of former earthquake is off coast of Japanese archipelago and the magnitude of major interplate earthquake is around 8. On the other hand, the intraplate earthquakes occur in inland of Japanese island but the magnitude is less than that of interplate earthquakes. The recurrence time of each intraplate earthquakes is much longer than that of interplate earthquakes; 100 to 150 years for typical interplate earthquake and at least 500 years for intraplate earthquakes.

Fig.1 is a plot of the loss of lives against magnitude of earthquake that occurred in 20th century. This figure implies that the magnitude of intraplate earthquakes is smaller that that of interplate earthquakes but the loss of lives due to intraplate earthquake is greater than that of interplate earthquakes. The plot at upper-right corner stands for the 1923 Kanto earthquake which is classified as interplate earthquake from tectonic point of view but its epicenter was very close to Tokyo area. Then this plot might be classified as inland earthquake from the view point of disaster. The magnitude of intraplate earthquake is less than that of interplate earthquakes but it occurs at areas close to urbanized area. This implies that the magnitude and affected area of inland earthquakes are smaller but the disaster in the area is much intensive compared to the interplate earthquake.

Most seismic design codes and local earthquake disaster mitigation plans consider both of interplate and intraplate earthquakes but resulting effect of each type of earthquake is not comparable. Japan has long written history of earthquakes of which rough estimates of magnitude and epicenter have been given. Therefore we can calculate the probability of occurrence and the expected values of intensity of ground shaking from the written history of earthquakes of the past.

In most of earthquake disaster mitigation plans of local governments, the effects of intraplate earthquake are taken into consideration in such way that the epicenter is assumed at a point apart 10 to 20 km from the area concerned without specifying the direction. This is unrealistic situation as a model of earthquake occurrence and this assumes that earthquakes never take place within 10 to 20 km whatever area is concerned.

Proposal

When the probabilistic approach is used in the seismic risk analysis, the expected value of ground motion is mainly governed by the interplate earthquake because the annual probability of occurrence of interplate earthquake is much larger than that of the intraplate earthquakes even though the number of intraplate earthquake surrounding the area concerned is much larger than that of interplate earthquake. Therefore the intraplate or inland earthquake is exerting less influence on the scenario earthquake compared with the interplate earthquake as far as the probabilistic approach is adopted.

Once we know that the intensity of ground shaking is intensive and many people are killed when an inland earthquake takes place near a mega-city, we should change our way of consideration of intraplate earthquake even though the probability of occurrence is small. Particularly, there are so many active faults in Kansai area and therefore people living in Kansai area are much more sensitive and conscious about the intraplate earthquake than people of other regions of Japan. Then local governments in Kansai area started reconsidering their earthquake disaster mitigation plan immediately after the Kobe earthquake and most of large cities have started paying much attention to the intraplate earthquake.

Fig.2 is illustrating the distribution of active faults in Kansai area. In Osaka, the prefectural and municipal governments are making investigation as a join project about these active faults in order to make clear the location and configuration of near field active faults with technical and financial supports of the central government. In the investigation, drilling and wave reflection methods are employed in exploration of existing faults.

Once the configuration of each active fault is determined, seismic motion on the ground surface is calculated by the procedures shown in Fig.3. The Green's function for short period range is determined by the empirical method. The ground motion at the site concerned is characterized by the source effects, path effects and site effects. It is known that the displacement Fourier spectrum at source is represented by the omega square model for earthquakes with magnitude less than about 5.

Path effect is considered in terms of spatial attenuation factor Q and the value determined by other investigation for the Kansai area is used in the analysis.

In order to evaluate the site effects, microzoning has been carried out by making use of the results of observation of microtremors, which were conducted at more than 1,000 sites in Osaka. It is known that the spectrum ratio of horizontal component to vertical component gives a good approximation of the frequency response characteristics at local site, which is used in zoning of the area.

Amplification characteristics in a zone is determined from the observed seismic wave properties due to small earthquake. As mentioned above, since the source spectrum is represented by the omega square model for small earthquakes, the spectrum representing the frequency characteristics is obtained by removing the source and path effects from observed wave forms. Applying this procedure to several small seismic records, the average value was used to represent the site effects.

Spectrum on the ground surface is obtained by multiplying the amplification spectrum representing the site effects to the source spectrum represented by the omega square model, considering the attenuation characteristics. Time history of the Green's function is calculated from the spectrum by Boore (1983).

On the other hand, the Green's function for longer period range is determined by the procedure as follows. The evaluation of effects of multiple reflection in a basin structure of ground is most important factor for site effects in longer period range. This effect is considered to be a reason of intensive shaking during the Kobe earthquake in the zone alike a belt extending east-west direction between the coast and mountain range in the area. Since this is strongly governed by the relative position of the point concerned from the origin of the earthquake and the structure of sedimental deposit, it is difficult to determine these effects from the records of earthquakes of the past and therefore a theoretical approach has been employed by making use of three dimensional numerical simulation of elastic wave transmission in a basin structure.

Based on the Green's functions for short and long period range, the hybrid Green's function is calculated by summing two Green's functions on the time domain.

In case of larger earthquakes, the ground motion is synthesized as a superposition of small earthquakes that follows the omega square model, adjusting the location of asperities and location of origin of rupture, and corresponding to the rupture process assumed on each fault.

During the Kobe earthquake, many bridge piers and buildings were collapsed and the ductility of those structures that were constructed in 1960's were not large enough to survive the strong shaking of the event. In order to rebuilt the collapsed structures and strengthen the existing ones, the tentative design spectrum for bridge structures was developed by the national government and many structures have been strengthened by governmental agencies and public corporations. This spectrum was developed and issued within a few months after the event. The spectrum have been used throughout the country regardless to the seismicity of each region. Then, the local governments of Kansai area have been developing, with aid of university researchers and structural engineers, the design spectrum corresponding to the synthesized ground motion that is determined for each site by the method described above.

Fig.4 is an example of a strength demand spectrum which gives the required strength and ductility of structure, which was developped in the investigation of this project. μ in the figure stands for the ductility factor and $\mu=1$ is the case of linear elastic structure. The figure will be self explaining. Moreover, evaluation of seismic performance and measures of strengthening of such structures as highway facilities, river banks, dams, sewage facilities and harbor facilities are being undertaken by several teams of specialists that are led by university researchers. In these analyses, the time series that are determined by the above mentioned are utilized.

Cooperative Mechanism

The Ministry of Education, Science, Sports and Culture (Monhusho) has granted "Fundamental Research for Mitigation of Urban Disaster by Near-Field Earthquakes" for four years from 1996. This is a Grant-in-Aid for Scientific Research on Priority Areas and the principal investigator is the author of the present paper. This project has 8 planned research subjects and 47 individual research programs have been approved among 143 proposals.

The main subjects of the project are the investigation of the near field ground motion due to inland active faults and its effects on structures and the real time management of post earthquake issues. The former subject will provide the scientific bases for establishment of the earthquake disaster mitigation plan to be implemented by local governments.

As mentioned above, however, most of Japanese seismic design codes and earthquake disaster mitigation plans have evaluated less effects of inland faults compared to the interplate earthquakes, except the aseismic design of nuclear power plants which are mostly constructed on rock site. Therefore, the seismic problems of structures which are located on stiff and soft soil and subjected to inland active faults are subjects of research to be conducted urgently. Moreover, the seismologists warn the high possibility of successive occurrence of major inland earthquakes in Kansai area based on the statistical analysis of Japanese history of earthquakes of 1200 years. In this sense, we have very short time until the next big one takes place.

The United States had three disastrous earthquakes in the last 25 years; 1971 San Fernando earthquake, 1989 Loma Prieta earthquake and 1994 Northridge earthquake. All of them occurred near the urbanized areas and provided a number of near field ground motion records. Then, the investigation on the near field ground motion is developed very well in the United States and therefore we will be able to learn a lot from the joint research between two countries.

Monbusho of Japanese government is considering to set up a mechanism of joint research between both countries as shown in Fig.5. This program will be implemented in the mechanism of the Japan-United States Science and Technology Agreement and the tentative tittle of the research program will be "Joint Research on Urban Earthquake Disaster Mitigation ". Both countries have liaison person and the Japanese liaison is the author of the present paper. Most of university researchers who are engaged in earthquake engineering are involved in the research team of the core group of Japanese side in the framework shown in Fig.5. Now, Monbusho is trying to raise fund for several research programs and the Japan Society for the Promotion of Science (JSPS) will support partly in some cases.

Related Issues

In the earthquake engineering community, a few joint research programs have been undertaken and planned between Japan and the United States. One is "Post-Earthquake Reconstruction Strategies" which is supported by JSPS in Japanese side and by the National Sciences Foundation in U.S. side. The principal investigators are Prof. T. Katayama of INCEDE at University of Tokyo and Prof. G. Lee of NCEER at New York State University. The other one is "Consensus on Acceptable Risk in Urban Earthquake Disaster" which is a Monbusho International Scientific Research Program: Joint Research. Prof. H. Kameda of DPRI at Kyoto University is the principal investigator of Japanese side and the that of U.S. side is Prof. M. Shinozuka of University of Southern California.

Addition to these projects, US-Japan joint seminar is proposed to the JSPS and NSF by Prof. K. Toki of Kyoto University and Prof. W. Iwan of California Institute of Technology under the tittle "Mitigation of Near-Field Earthquake Damage in Urban Areas--Comparative Studies of the Northridge and Kobe Earthquake" This proposal has not been granted yet and the result of review will come out next year. Moreover the fourth project has been proposed by two research centers of both countries as a center-to-center project. The proposal of U.S. side has been submitted from Southern California Earthquake Center (principal investigator: Prof. M. Shinozuka of University of Southern California) and already approved by NSF. The principal investigator of Japan side is Prof. K. Irikura of DPRI at Kyoto University .

The first two projects have started in 1996 and both projects are mainly concerned with the social affairs and soft ware issues of earthquake disasters. The third one is putting emphasis on the strong ground motion and structural safety to it. The major target of the fourth project is to find the possibility of introducing and developing the intelligent materials and systems in earthquake disaster mitigation issues.

In the mean time, JSPS has granted the research program for structural control under dynamic loadings. This project has started in 1996 as 5 years program and about $ one million is provided for 1996. This project is not an international joint program but a domestic one. However, both countries have the panel for structural control and these panels have had good correspondence for last 3 years. Then U.S. side is expected to take some action to respond to Japanese side.

As mentioned above, there are individual efforts to promote joint researches on earthquake disaster mitigation issues between two countries. Then, in order to establish a strong collaboration among these on-going and under planning projects and to discuss the future direction, we are now considering to hold a workshop in Japan next year. This workshop is to succeed the previous one that was held in December 1995 in Hawaii under the leadership of Prof. T. Okada of University of Tokyo (then) and Prof. S.A. Mehin of University of California at Berkeley. In this meeting, the necessity of collaboration between Japan and U.S. for earthquake disaster mitigation was discussed and the research areas to be implemented with high priority were proposed. After this meeting, intensive discussions between two countries have been continued and these activities were succeeded to the U.S.-Japan Common Agenda of 1996. In this context, the workshop of next year will be most important one for further development of partnership for mitigation of earthquake disaster in mega cities of both countries.

<u>Key References</u>

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Irukura, K. (1986), Prediction of Strong Acceleration Motions using Empirical Green's Function, Proc. 7th Japan Earthq. Eng. Sym., 151-156.

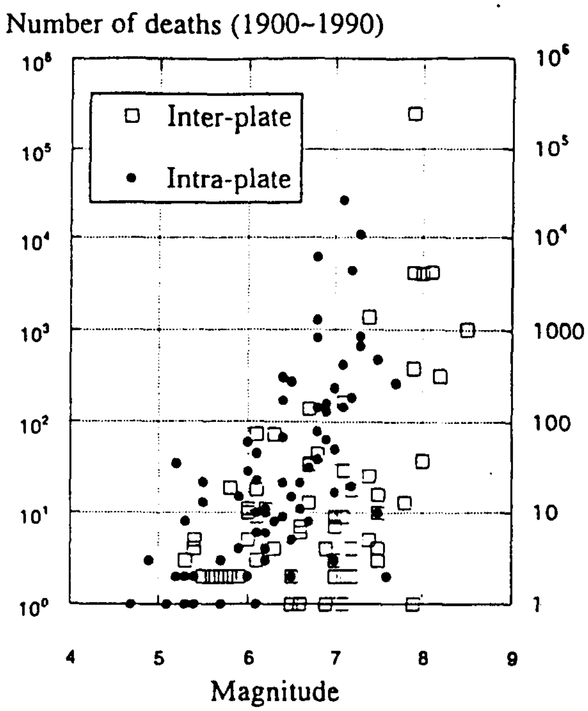

Fig. 1 Loss of lives due to interplate and intraplate earthquake in Japan

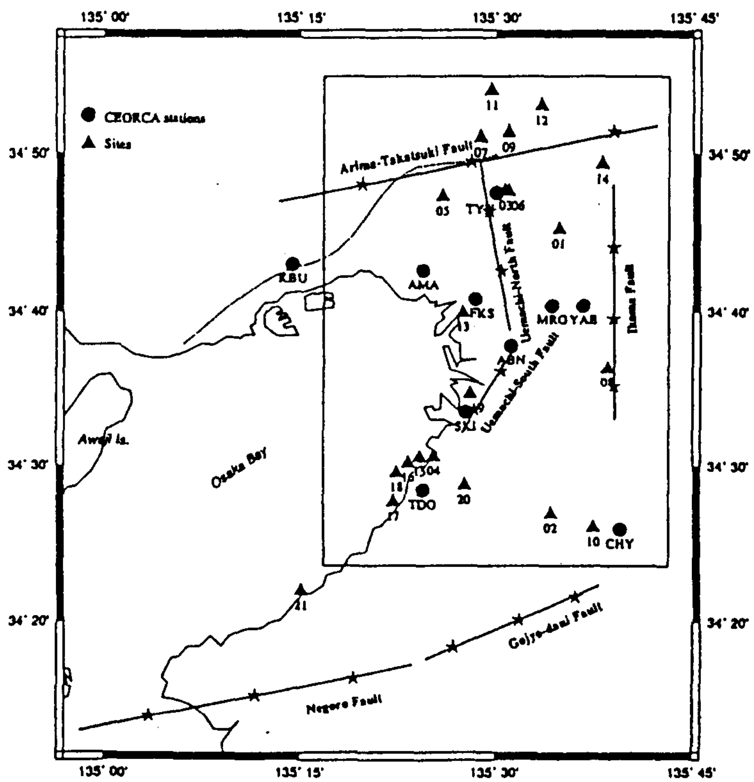

Fig. 2 Active faults in Kansai area

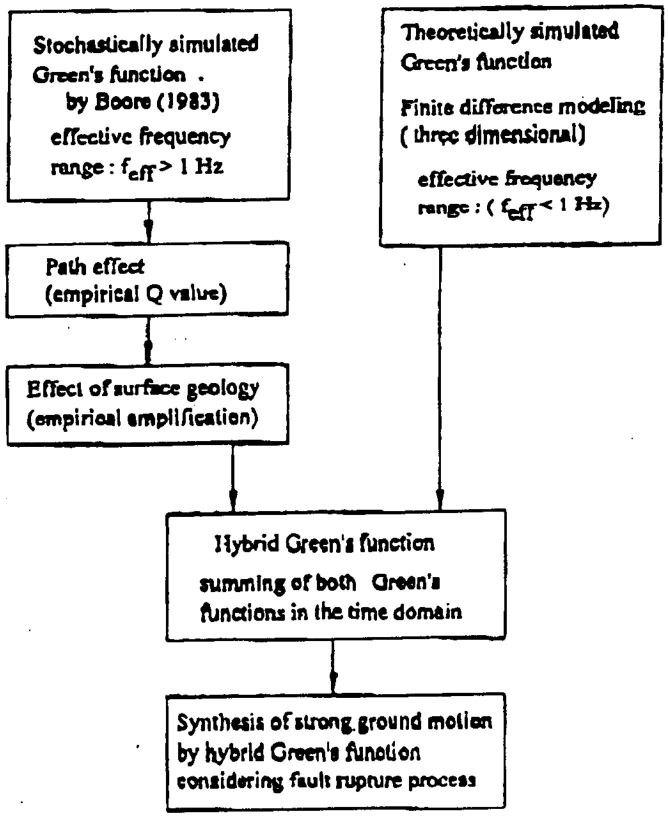

Fig. 3 Simulation of Strong Ground Motion by hybrid Green's function

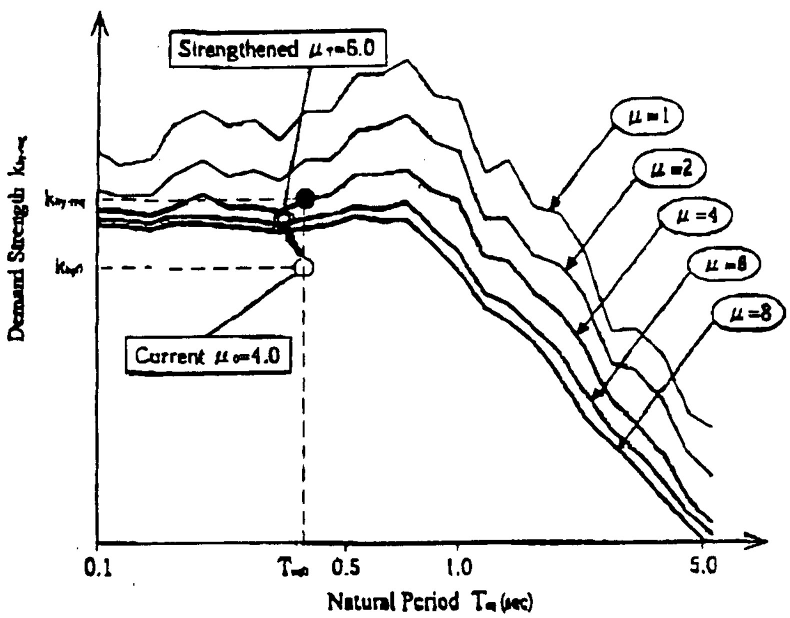

Fig. 4 Strength demand spectrum

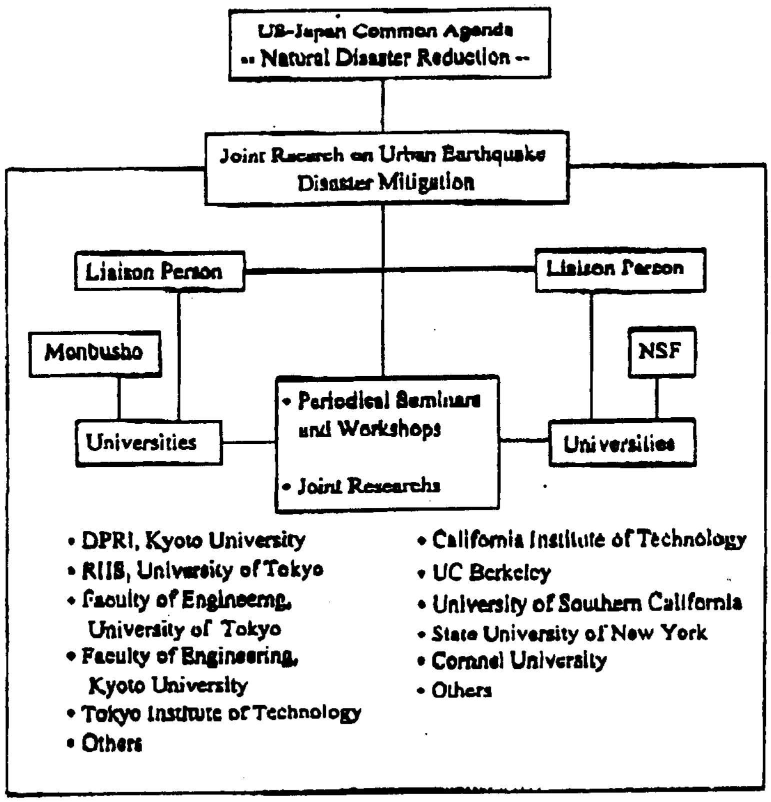

Fig.5 Framework of joint research between Japanese and U.S. universities